Advanced Fuel Forms for Nuclear Thermal Propulsion Applications

Completed Technology Project (2015 - 2018)

Project Introduction

In NASA's 2014 Strategic Plan, Objective 1 specified the necessity to "expand human presence into the solar system and to the surface of mars to advance exploration, science, innovation, benefits to humanity, and international collaboration". As a part of fulfilling this objective, the strategic plan aims to send a human mission to mars in the 2030s. The advancement of in-space propulsion technologies is essential in order to fulfill this objective. NASA's most recent In-Space Propulsion Systems Road Map (TABS 02) cites the need to develop technologies which "enable much more effective exploration of our Solar System". More effective in-space propulsion systems must be mission enabling as well as reduce transit times, increase payload mass, and decrease costs. For a human mars mission, the in-space propulsion of choice should be capable of high thrust levels and high specific impulse to reduce transit time. A non-chemical propulsion technology, nuclear thermal propulsion (NTP), has been extensively tested in the United States and former Soviet Union. A NTP engine has the potential for twice the specific impulse of the best chemical engines (880 - 900 s) and 25 - 500 klbf thrust (100 - 2,200 kN). Thus, this technology is expected to reduce transit time and launch mass, therefore reducing mission costs. These attributes allow increased mission flexibility by increasing available payload mass and enabling longer stays on mars. Because of the unique advantages nuclear thermal propulsion can offer, in the National Resource Council's review of NASA's InSpace Propulsion Systems Roadmap, nuclear thermal propulsion was ranked as a high priority for in-space propulsion development. Under NSTRF15, the goal of this project is to aid the development of nuclear fuel forms for use in a nuclear thermal rocket (NTR). This will be completed through the identification and qualification of nuclear fuel form property data using non-nuclear testing. This data is essential in order to model fuel behavior and predict fuel performance as well as prepare nuclear fuel forms for eventual irradiation testing. Previous NTP programs (such as the NERVA/Rover program) took the approach of testing nuclear fuels through nuclear operation of a full scale reactor core. However, this methodology is costly and subject to stringent safety requirements. Recent research developments have shown that NTP fuel forms cannot be identically "re-captured" from past NTP programs because of the loss of manufacturing capabilities. Therefore, new manufacturing processes must be developed to mature fuel forms to be able to operate under the desired conditions for the NTR core and new property data must be obtained. Lessons learned from past NTP programs have shown that certain thermal and material properties of past NTP fuel forms directly correlate to the potential for successful NTR operation and high temperature performance. Since new manufacturing methods are needed for the development of NTP fuel forms, the thermal and material properties data archived from previous programs is not directly applicable for fuel performance simulations and the ultimate fuel selection process. The primary research objective of this project is to characterize a NTP fuel form which can withstand operating conditions of over 2800 K in a hot hydrogen environment. Secondary objectives will evaluate fuel performance at expected

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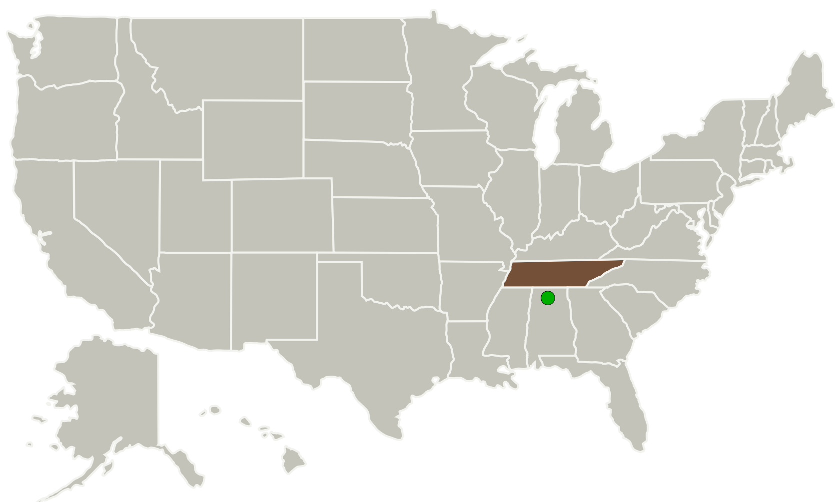
Table of Contents

in-core vibration, pressure, and temperature gradients associated with operation. In order to meet project objectives, the methods of this project will consist of: 1) selection of of fuel form chemistry and manufacturing processes, 2) Non-nuclear fuel testing and characterization of fuel material and thermal properties, and 3) Computational fuel modeling for expected operating conditions. NASA Marshall Spaceflight Center and affiliated research centers will provide the unique research facilities to ensure this project's success.

Anticipated Benefits

The goal of this project is to aid the development of nuclear fuel forms for use in a nuclear thermal rocket (NTR).

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
The University of Tennessee-Knoxville(UT-K)	Lead Organization	Academia	Knoxville, Tennessee
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

The University of Tennessee-Knoxville (UT-K)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Steven Zinkle

Co-Investigator:

Kelsa B Palomares

Primary U.S. Work Locations

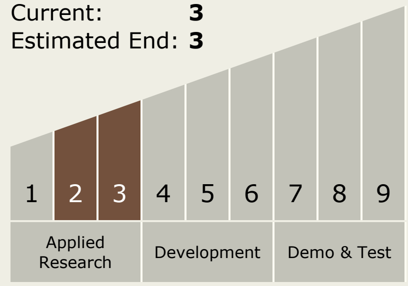
Tennessee

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX01 Propulsion Systems
  └─ TX01.4 Advanced Propulsion
    └─ TX01.4.3 Nuclear Thermal Propulsion

Target Destinations

Earth, The Moon, Mars